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# Status and future prospects of renewable energy in Iraq

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ABSTRACT

Iraq suffers from electricity shortages, and many challenges will have to be overcome to meet future increases in electrical demands. This investigation found that solar, wind and biomass energy are not being utilized sufficiently at present, but these energies could play an important role in the future of Iraq's renewable energy. Additionally, the potential of offshore-wind energy in the Gulf (near Basrah in the southern part of Iraq) needs to be investigated. The Iraqi government's attempts to utilize renewable energy have been discussed. This paper aims to review and discuss the status and future of renewable energy in Iraq. The uses of renewable energy sources, such as solar, wind and biomass, have been reviewed. This paper concludes with recommendations for the utilization of these energy resources.



**Contents**



## 1. Introduction

Internationally, there is an increased demand for energy, especially electrical energy. Not only are oil prices increasing but pollution continues to rise due to the burning of fossil fuels, and the probability of oil supply depletion remains. All of these issues encourage the investigation of using solar, wind and other renewable energies for the generation of electrical power [1–4].

Iraq is a member of the Organization of Petroleum Exporting Countries (OPEC) and covers an area in excess of 430,000 km$^2$, though the precise figure varies from one source to another and depends on the inclusion of both land and water areas. Iraq's Gulf coastline is only 58 km in length (see Fig. 1) [5]. Four main geographical zones have been recognized [6–8] and are described briefly as follows:

- Desert plateau: Approximately 40% of Iraqi territory. A broad, stony plain with scattered stretches of sand lying west and southwest of the Euphrates River. A network of seasonal watercourses (or wadis) runs from the border to the Euphrates River.
- Northeastern highlands: Approximately 20% of Iraqi territory. This region extends south from the border between Mosul to Kirkuk toward the Iraqi borders with Turkey and Iran and has mountain ranges of up to 3,600 m in altitude.
- Uplands region: Approximately 10% of Iraqi territory. A transitional area between the highlands and the desert plateau located between the Tigris north of Samarra and the Euphrates north of Hit that forms part of a larger natural area extending into Syria and Turkey.

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- Alluvial plain: Approximately 30% of Iraqi territory. Formed by the combined deltas of the Tigris and Euphrates Rivers. This region begins north of Baghdad and extends to the Gulf [9].

The population of Iraq rose from 14 million in 1980 to 32 million in 2010 and is expected to increase to approximately 64 million in 2050 [10]. However, actual density varies from 5 inhabitants/km$^2$ in the western desert province of Al-Anbar province to more than 170 inhabitants/km$^2$ in the fertile lowlands of Babil (Babylon). Approximately 75% of the population is concentrated in urban centers [11].

The growth rate of the population in Iraq has increased from 2.75% in 1980–1985 to 3.23% in 1995–2000. The growth rate then decreased to 2.72% in 2000–2005 and is expected to reach 1.09% in 2045–2050 [12].

There are various raw materials available in Iraq from multiple geographic sources. Most of the materials have a wide geographic distribution, which allows for a degree of flexibility in choosing locations. There is an abundance of raw material that has not been optimally exploited. Oil is the most important raw material to the economy of Iraq. The certified oil reserve in Iraq is estimated at 115 billion barrels. The undiscovered oil reserve is more than fixed, and thus, Iraq is considered to have the second largest oil reserve in the world after the Kingdom of Saudi Arabia. These estimates indicate that the Iraqi oil reserve reaches 300 billion barrels. The production of oil in 2009 was 2,399,000 bbl/day, as shown in Fig. 2a.




**Fig. 1.** Map of Iraq and border nations. (From: www.cia.gov on 17 December 2011).

Although natural gas (NG) is burned directly due to its occurrence with oil, it is currently considered the Iraqi economy's second most important raw material. The fixed reserve of Iraqi gas is approximately 1.3 trillion cubic meters; therefore, Iraq possesses 8.1% of the worldwide fixed reserve of natural gas. With this amount of natural gas reserve, Iraq ranks tenth in the world among countries rich in natural gas. There are many other raw materials, such as sulfur, phosphate and white clay, that have less of an importance to and share of the Iraqi economy. The production of NG in 2009 was 1,880,000,000 m$^3$, as shown in Fig. 2b.

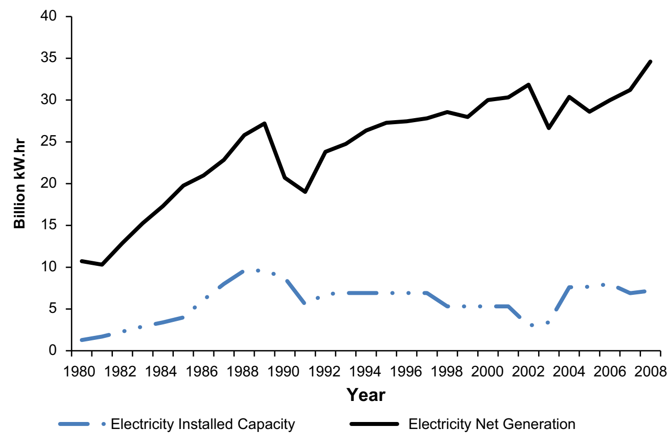



**Fig. 3.** Projection of the peak demand in Iraq until 2008.

**Table 1**
New stations and capacities with the used fuel.

| Location | Capacity MW | Fuel |
|---|---|---|
| Shat Al Arab | 125 × 6 | Fuel oil/Al-Basra Refinery |
| Al-Khairat | 125 × 6 | Fuel oil/Al-Basra Refinery |
| Al-Anbar | 125 × 4 | Fuel oil/Carbala Refinery |
| Al-Naseriya | 125 × 4 | Fuel oil/Al-Naseriya Refinery |
| Al-Doura/Location 3 | 125 × 6 | Fuel oil/Al-Doura Refinery |
| Al-Doura/Location 2 | 125 × 4 | Fuel oil/Al-Doura Refinery |
| Nineveh | 125 × 6 | Fuel oil/Al-Kasak Refinery |
| Al-Dewaneia | 125 × 4 | Two units of gas and two unit of fuel oil |
| AL-Qudus | 125 × 2 | Fuel oil/Gas at future |
| Al-Amara | 125 × 2 | Fuel oil/Al- Amara Refinery |
| Wasit | 125 × 2 | |
| Al-Samawa | 125 × 4 | Fuel oil/ Al-Samawa Refinery |
| Al-Mansouriya | 125 × 2 | Gas from Al-Mansoriya field |
| Al-Najaf | 125 × 4 | Two units of gas and two units of fuel oil |

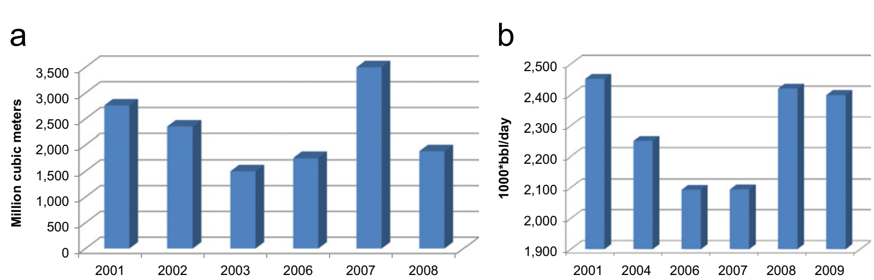



**Fig. 2.** Production of (a) oil and (b) natural gas.

**Table 2**
New power generation stations using NG.

| No. | Project | Location | Fuel used | Capacity |
|---|---|---|---|---|
| 1 | Al-Garaf station | TheeQar | Fuel oil/NG | 125 MW |
| 2 | Al-Garaf steam station | TheeQar | Natural gas | 300 MW |
| 3 | Al-Khairat steam station | Karbala | Fuel oil/NG | 300 MW |
| 4 | The North steam station | Al-Mousel | Fuel oil/NG | 300 MW |
| 5 | The North steam station | Al-Anbar | Crude oil/Fuel oil/NG | 300 MW |
| 6 | Shat Al-Arab Basra steam station | Al-Basra | Fuel oil/NG | 300 MW |

In Iraq, finding new resources of energy is not difficult because of how rich the country is in oil. However, Iraq does suffer from a growing shortage of electrical energy because of an increasing rise in demand (see Fig. 3). Electrical power generation stations fail to comply with the demand for power because of limited production capabilities and numerous defects due to deterioration. Similar to many other nations, the interest in renewable energy sources such as solar energy has increased in Iraq [12]. Iraq is predicted to be one of the richest countries in renewable energy resources.

Iraqi electricity consumption in 2009 was 52 billion kWh. Iraq's electricity infrastructure was severely damaged during the Gulf War, suffered from a lack of investment and available equipment while under sanctions, and suffered further following the invasion in 2003. Iraq requires more power day-by-day because of increased demands and population growth. Increased power is needed to not only to cover daily power shortfalls but also to support economic development. According to the Ministry of Electricity, the peak demand in 2008 was 12000 MW of power; however, only 6000 MW was supplied. This deficit is likely to grow to 25000 MW by 2020. Until now, renewable energies did not comprise any percentage of the generated power [13].

The Ministry of Electricity contracted with numerous companies to construct additional power generation stations. The contracts were designed to maintain Iraqi dependence on oil and NG because those are the fuels used in these stations. Table 1 represents the newly contracted stations and the fuel used (with its source).

After the recent invention of NG extraction processes and trends to use NG as fuel for power generation, many new stations have been contracted to operate with diesel fuel and NG. Table 2 represents the stations and their locations, and it appears that the new power stations consume fossil fuel.

Iraq's demand/supply gap is 133.33% on average, and progressive states have experienced a gap in excess of 150%. The average energy usage per capita is expected to increase because Iraq has a growing economy [14]. The electricity sector in Iraq requires large investments to fulfill the increasing demand for electrical power. According to the National Development Strategy issued by the Ministry of Planning and Development Cooperation, electrical power requirements are estimated to be $16 billion US dollars for the period between 2007 and 2010, and these estimates include governmental and private investments [15,16].

The net electricity generation (conventional thermal electricity and hydroelectricity power) increased from 12.86 (1980) to 34.6 billion kWh. While the net electricity consumption (net generation, electricity import, electricity export, and electricity losses) increased from 10.167 to 33.5 billion kWh. The installed electricity capacity increased from 1.3 to 7.2 GWe in 1980 and 2008, respectively, as shown in Fig. 3.

The present paper explores the status of and future prospects for renewable energy in Iraq. The potential of renewable energy sources has been revised and a review has been completed of available renewable energy options in the industrial and electrical sectors. The aim of this study is to promote public awareness and inspire local governments to dedicate additional efforts and funds for renewable energy utilization.

## 2. Solar energy in Iraq

Iraq is well-known for long hours of sunshine. Studies have shown that Iraq receives more than 3000 hours of solar radiance per year in Baghdad alone. The hourly solar intensity varied between 416 W/m$^2$ in January to 833 W/m$^2$ in June. Even the hours of sunshine in Spain cannot compete with the levels observed in Iraq [11]. In Iraq, the study of solar energy began after the 1973 energy crisis. Many studies were undertaken to determine equations for the representation of solar intensity in Baghdad. During that time in Iraq, numerous theoretical and practical studies were commenced to study domestic water heaters and coolers that used solar energy [17] and build theoretical models that represented solar water heaters. The results showed congruity between practical and theoretical results [18,19]. Subsequently, the focus of the studies shifted toward finding possible ways to improve the efficiency of solar applications for power generation [4]. Mohamed-Rassal (2008) [20] studied the potential use of solar energy in hydrogen production. Experimental investigations on trombe walls confirmed the possibility of using solar energy during Iraqi winters [21,22]. Chaichan (2009) [23] showed the success of solar salt gradient ponds and the use of the stored energy in warming rooms.

The viability of solar radiation data is vital for the economical use of solar energy. The measurement of solar energy data in all Iraqi areas is essential for evaluating the advantages of using solar energy in Iraq [24]. Ahmed (1988) [25] mathematically correlated temperature, humidity and solar radiation period. These relationships were accurate in solar radiation assessments. Relationship constants were found for three areas in Iraq. Fig. 4 shows a yearly and monthly solar radiation map for the radiation periods of 24 stations throughout the Iraqi territories [26].

Previous Iraqi experiments using photovoltaic (PV) cells were unsuccessful. Photovoltaic cells were used in community street lights but were unsuccessful because the cells had a low efficiency factor and Iraqi weather is characterized by dusty days. These factors reduced the range of use of PV cells, though the cells did find limited application in individual home rooftop systems, community water pumping stations, and areas where the terrain makes it difficult to access the power grid [27].

The fundamental characteristics of solar radiation in Iraq are summarized as follows:

- In the northern territory, the yearly changes varied by approximately 300%, varying from 7 MJ/m$^2$ in December and January to 23 MJ/m$^2$ in June. In the southern territories, the yearly changes varied by approximately 200%, varying from 13 MJ/m$^2$ in December and January to 27 MJ/ m$^2$ in June and July. In the central territories, the yearly changes varied by approximately 250% and can be considered as the average of yearly changes between the northern and southern territories.
- Solar radiation descends strongly from north to south and increases in winter and decreases in summer. There is a much more uniform distribution of solar radiation throughout the Iraqi territories in summer (from June to August).

- The decline of solar energy from east to west is considered small and prone to appraisal error.
- Solar radiation appraisal depends on relationships derived from data that were measured by meteorology stations in cities and large towns. These locations receive less radiation than the surrounding areas due to pollution, thus the actual levels of radiation are higher than the measured values [13].

### 2.1. Photovoltaic (PV) systems

- Due to uniform distribution of solar radiation throughout Iraq, solar PV technology is suitable for producing electricity throughout Iraq.
- Solar PV technology is also suitable for off-grid electricity generation in power plants in rural desert areas.

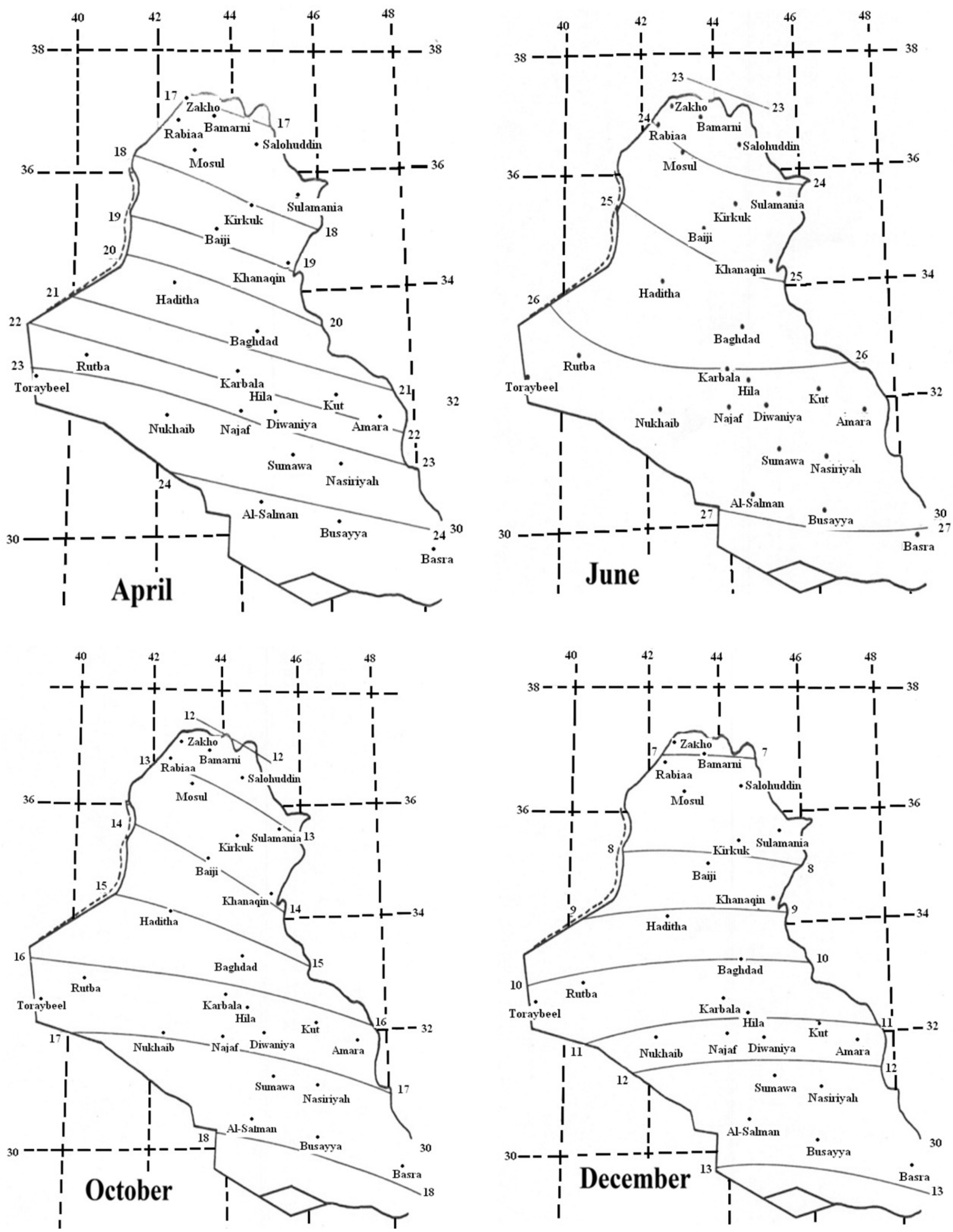



**Fig. 4.** Solar radiation lines for other months in Iraq [25].

- The efficiency of PV cells is influenced by high air temperature and dust contamination. Due to the dusty weather in Iraq, it is important to investigate the type of dust, density of dust, rate of accumulation of dust, and the effect of dust on the PV performance.

### 2.2. Solar thermal systems

- Concentrated solar power (CSP) is expected to be very well suited to the long days of sunshine and the high temperatures found in Iraq.
- Investigations are underway in Iraq to improve the use of CSP during high temperature weather conditions.
- The use of solar water heater systems by domestic loads has increased.

PV and/or CSP system implementations have shown that their efficiency and reliability depend on many factors, including orientation (longitude and latitude), environment (solar intensity, temperature, humidity, wind, dust, rain, pollution, etc.) and the PV technology used. Thus, before committing to a large-scale (in megawatts) PV or CSP project, a thorough investigation of the above factors is essential.

## 3. Wind energy in Iraq

Numerous research studies have been conducted to investigate wind energy in Iraq. Twenty-three stations were chosen for analysis. The daily model for wind velocity has maximum values in the middle of the day and the early morning hours. These maximum values varied between 5 to 10 m/s. The wind velocity in summer is higher than in winter, which is fortunate because the demands on electrical energy increase in summer compared with winter because of increased cooling and ventilation loads [27].

Iraq can be divided into three territories. The first territory represents 48% of Iraq and has wind velocities that vary between 2–3 m/s. The second territory represents 35% of Iraq and has wind velocities that vary between 3.1 to 4.9 m/s. The third territory represents 8% of Iraq and has relatively high wind velocities of more than 5 m/s. These studies demonstrated that the approximate energy densities for wind territories are as follows: 174 W/m$^2$ in Al-Emarra, 194 W/m$^2$ in Al-Nekhaib, 337 W/m$^2$ in Al-Kout, 353 W/m$^2$ in Ana, and 378 W/m$^2$ in Al-Naseria. From these results, an average energy of approximately 287.2 W/m$^2$ can be obtained [13].

## 4. Biomass energy in Iraq

Biomass includes solid biomass (organic, non-fossilized material of biological origins), biogas (principally methane and carbon dioxide produced by anaerobic digestion of biomass and combusted to produce heat and/or power), liquid biofuel (bio-based liquid fuel from biomass transformation that is mainly used in transportation applications), and municipal waste (waste produced by the residential, commercial and public service sectors and incinerated in specific installations to produce heat and/or power) [28,29].

The most successful conversion of biomass to energy is the production of biodiesel from sugar cane and corn. Dates and sugar cane (in addition to other types of canes grown in Al-Ahwar) can also be used to produce bio-ethanol. All of these plants can be transplanted to Iraq in large quantities. Currently, the Iraqi agriculture sector suffers from outdated technology, inadequate farm credit, and a general state of disrepair of irrigation and greater agricultural infrastructures [30,31]. These conditions can be considered the main factors for neglecting biomass energy.

Iraq is very rich in biomass; unfortunately, this sector is highly neglected by the Iraqi government. The abundance of newly found oil and NG reduced the need to investigate biomass as an energy alternative. However, this situation has not prevented Iraqi researchers from studying biomass energy. Many researchers studied the effect of using bio-ethanol and methanol in compression- and spark-ignition engines. These studies confirm the usefulness of adding ethanol and methanol to conventional Iraqi diesel and gasoline. Iraqi diesel suffers from a high sulfur content (approximately 10000 ppm), while Iraqi gasoline suffers from a low octane number. These two conditions can be treated by using bio-ethanol or methanol [31,32].

## 5. Conclusions

Iraq's major achievements and the authors' recommendations on renewable energy development can be summarized as follows:

- The solar energy density in Iraq is among the highest in the world. Additionally, there is significant wind energy potential in several areas in Iraq.
- The potential for utilizing biomass energy for electricity production is found to be limited in comparison with solar and wind energy but could be sufficient if utilized efficiently.
- More studies need to investigate off-shore wind (in the Arab Gulf near Basra) and geothermal energies.
- Government support is required for implementing small, renewable energy pilot projects, especially those that serve people in rural areas.
- Financial support for studies that investigate renewable energy in Iraq and its applications is required.
- Introducing solar thermal collectors in public buildings to produce hot tap water can be considered a first step towards reducing dependence on fossil fuel resources.
- Fourth year projects in renewable energy are encouraged and sponsored. A particular emphasis is placed on research and graduate M.Sc. and Ph.D. programs in renewable energy science that will serve as workforce catalysts for promoting increased use of renewable energies in Iraq and encourage the gradual move toward a more conscious and sustainable use of energy sources.

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